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COST OF COMBINE HARVESTING IN MINNESOTA

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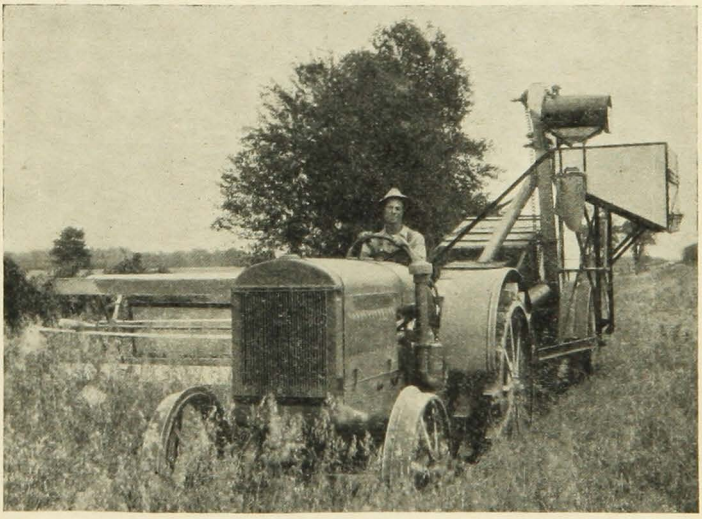

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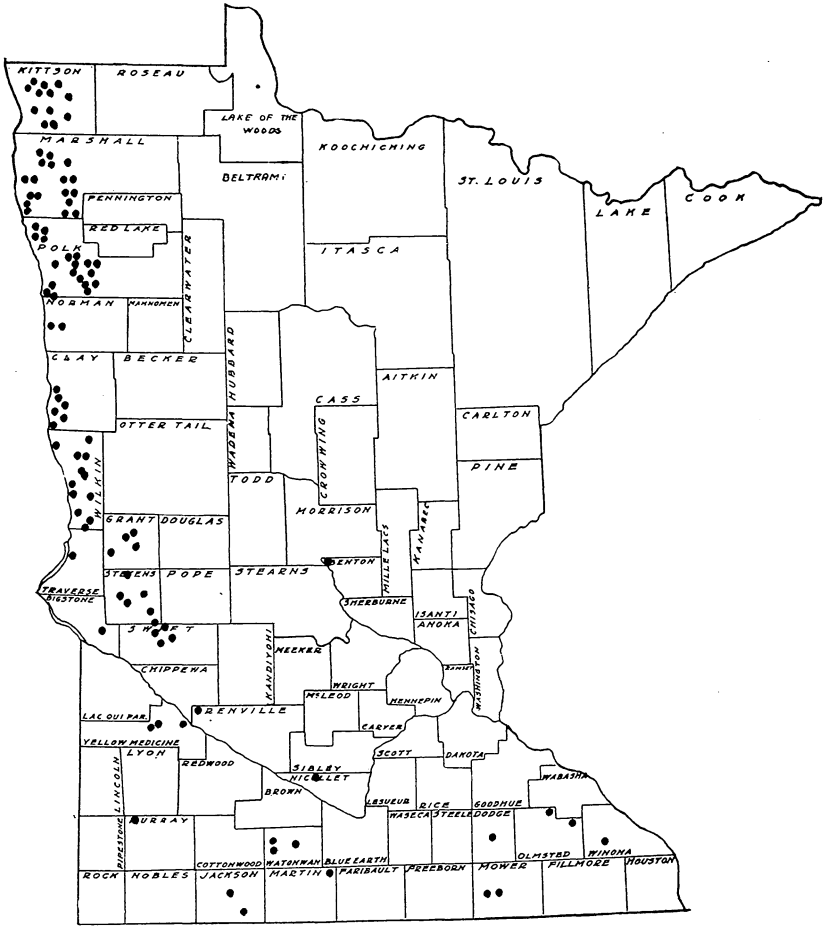

Fig. 1. Location of Combines in Use in Minnesota in 1929

Most of the combines in Minnesota are found on the large farms in the western and northwestern part of the state where a large proportion of the land is in small grain. Only a few machines are in use in southern Minnesota where farms are smaller and corn is relatively more important than small grains.

COST OF COMBINE HARVESTING IN MINNESOTA

GEORGE A. POND and LOUIS B. BASSETT

INTRODUCTION

The combine harvester was first used in Minnesota in 1927. Eleven machines were in operation that year. The number increased to 49 in 1928 and to approximately 110 in 1929. The location of these machines is shown in Figure 1. Most of them are used on the relatively large farms of west central and northwestern Minnesota where a considerable acreage of small grains is grown altho a few are scattered through the southern part of the state where farms are smaller and livestock production predominates. The introduction of any piece of farm equipment that materially changes existing methods of production introduces a number of problems. Some of these, in case of the combine, are engineering and agronomic, involving the adaptation of the new machine, and the crops as well, to the new method of harvesting. Others are economic and deal with relative costs and economies as compared with previous methods. During the past two harvest seasons the University of Minnesota Agricultural Experiment Station has been conducting a study of combine-harvester problems in co-operation with the United States Department of Agriculture. A general report covering all phases of the study in 1928 was published in July, 1929, as Minnesota Agricultural Experiment Station Bulletin 256.[1] The reader is referred to that publication for further information as to the history and development of the combine and for the engineering and agronomic phases of the work done in 1928.

More detailed results dealing with the cost of operation of combines during the harvest season of 1928 and 1929 are presented in this bulletin.

METHOD OF STUDY

The data used in this study were obtained from daily records kept by combine operators supplemented with a survey at the end of the season.[2] The daily reports included records of acres cut; hours of labor; use of tractors, trucks, and horses; gasoline and oil consumption;

[1] Schwantes, A. J., Pond, G. A., Arny, A. C., Bailey, C. H., Black, R. H., Reynoldson, L. A., and Humphries, W. R., The Combine Harvester in Minnesota, Minnesota Agricultural Experiment Station Bulletin 256, July, 1929.

[2] The authors wish to acknowledge the valuable assistance and co-operation of the following parties who aided them in this study: Arthur J. Schwantes, Division of Agricultural Engineering, who secured the names of combine owners and solicited their co-operation; Willard P. Ranney and George A. Sallee, Division of Farm Management and Agricultural Economics, who assisted with the field work; and the combine owners who furnished the information on which this study is based.

and similar information regarding operating costs. At the end of the season each operator was interviewed, his record was checked and completed, and information regarding his experience and principal problems was secured. Records were obtained from 13 operators in 1928 and from 42 to 1929. Ten who furnished records in 1928 also reported in 1929 so that a record of 45 machines or 41 per cent of all machines in operation in the state in 1929 was secured. Figure 2 shows the location of the 42 operators, which, in general, corresponds to the distribution in Figure 1. Some information was obtained from men who did not keep complete cost records.

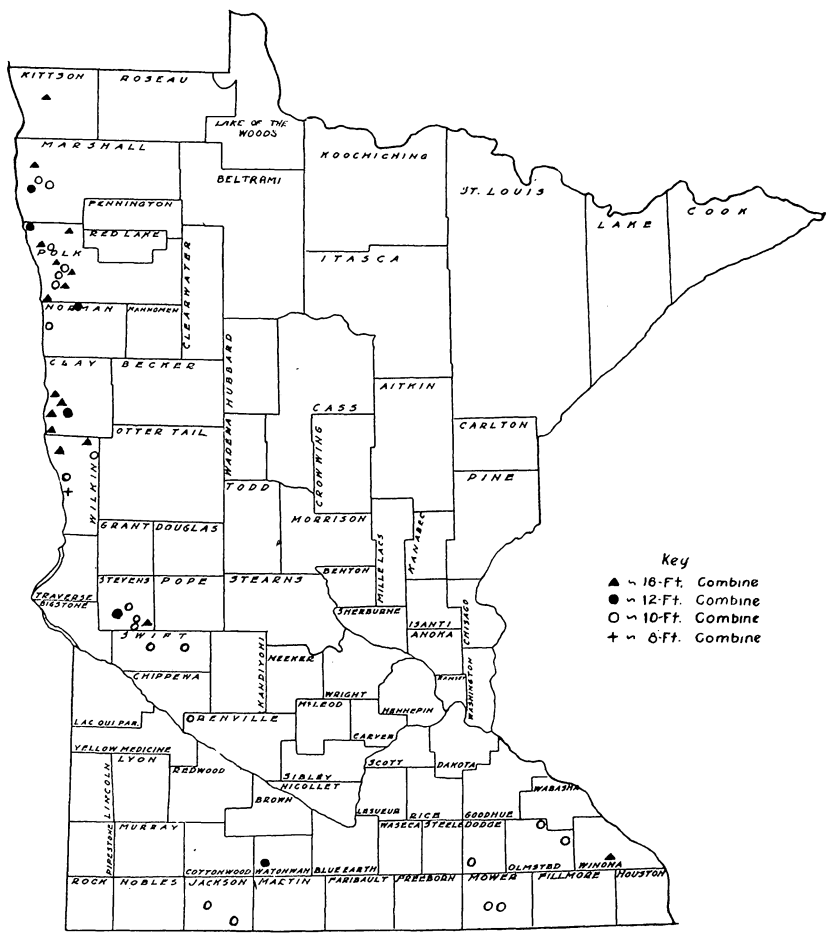

Fig. 2. Location of Combines Included in This Study

The combines in this study are distributed throughout the state in about the same proportion as the total number of machines in use.

DESCRIPTION OF FARMS

Some facts regarding the farms on which the combines are used are presented in Table I. The farms are more than three times larger than the average for the counties in which they are located. A larger proportion of these farms is in crops, most of which are small grains. The large capacity of the combine adapts it to the large farm. Farms using 10-foot combines, the smallest size in general use, are about 2.2 times as large as other farms in those counties. The 12-foot combines are used on farms 3.2 times as large as the county average and the 16-foot machines, on farms 4.7 times the average size. Of the 45 farms only 3 are smaller than the county average. The smallest farm on which a combine was used is 160 acres and the largest, 3,360 acres. Ten farms have more than 1,000 acres and 4 have 2,000 or more acres. Most of these farms are primarily small grain farms altho on some considerable livestock is maintained. The productive livestock as given in Table I includes cattle, hogs, sheep, and poultry. Altho these farms maintain much more livestock per farm than the county average, when size is considered the amount of stock per acre or per crop acre is about one-half as great. On 6 farms no productive livestock was kept and on 4 farms less than one unit per 100 acres. Seven farms maintained as much or more stock per 100 acres as the county average. In general the combines are used on large farms on which a large proportion of the land is in small grain and livestock production is relatively less important.

TABLE I

COMPARISON OF COMBINE FARMS WITH COUNTY AVERAGES*

	Forty-five combine farms	Average all farms in counties
Total acres per farm	766	240
Crop acres per farm	672	176
Acres of small grain per farm	432	94
Per cent crop land is of total in farm	88	73
Per cent small grain is of total crop land	64	53
Animal units of productive livestock†	31.6	18.7
Animal units of productive livestock per 100 acres	4.1	7.8
Animal units of productive livestock per 100 crop acres	5.0	11.1

* County averages weighted by number of combines in county.

† The following numbers of stock are considered one animal unit: 1 cow, 2 young cattle, 5 hogs, 10 pigs, 7 sheep, 14 lambs, 100 chickens.

Sixteen of the farmers using combines own their own farms, 6 rent all the land operated, and the remaining 23 own part and rent part of the land. Fifty-one per cent of all land on the farms studied is owned by the operator and 49 per cent is rented. Renting additional land is one way to secure a crop acreage large enough to provide profitable use for a combine.

WORK DONE BY COMBINES

The acreage and kind of crops harvested with a combine on the farms studied are given in Table II. Ninety-five per cent of the acres harvested was small-grain crops and 5 per cent sweet clover, red clover, alfalfa, and timothy seed. The variety of crops harvested with a combine in Minnesota makes possible a longer harvest season in this state than in sections where one crop predominates as it does in some sections of the wheat belt. The flax and clover crops follow the small-grain harvest and increase the acreage that can be handled with one machine. Using the combine for custom work enables the owner to utilize the machine nearest to capacity. Twenty-three per cent of all work done by the combines studied was custom work. The proportion of custom work increased from 8 per cent in 1928 to 27 per cent in 1929 . Six of the 13 farmers from whom reports were received in 1928 did custom work and 24 of the 42 in 1929.

TABLE II

CROPS HARVESTED WITH COMBINES STUDIED, 1928 AND 1929

Crop	1928	1929	Total	Per Cent
	Acres	Acres	Acres	
Barley	1416	6951	8367	32
Wheat	1461	5440	6901	26
Flax	1667	3286	4953	19
Oats	452	2677	3129	12
Rye	83	1230	1313	5
Sweet clover	147	1019	1166	4
Miscellaneous crops	130	366	496	2
Total	5356	20969	26325	100
Number of combine years	13	42	55	
Acres per combine per year	412	499	479	

The amount of work done by the different sized combines is given in Table III. In general, the 10-foot machines were not used as nearly to capacity as the larger machines. The average acreage per cutting foot for the season was 33 acres for the 10-foot machines, 42 for the 12-foot machines, and 41 for the 16-foot machines. There was, however, a wide range of use within each of the size groups and the maximum acreage per cutting foot for the 10-foot machine was nearly 50 per cent above that of the larger machines.

Nine of the 13 combine operators used windrowers in 1928. Of these, 7 windrowed all the grain combined and 2 about half of it. In 1929, 25 operators windrowed all the grain combined, 13 part, and 4 did not use a windrower at all. Of those using the windrower for part of the work, the proportion varied from 33 to 94 per cent and averaged 64 per cent. The use of windrowers is increasing. Sixty-nine per cent of the operators used them in 1928 and 90 per cent in 1929. The

proportion of the total acreage windrowed was 70 per cent in 1928 and 80 per cent in 1929.

TABLE III

ACREAGE HARVESTED PER MACHINE BY DIFFERENT SIZES OF COMBINES, 1928 AND 1929

Size of combine	Number of machines	Average	Maximum	Minimum
8-foot	1	390	...	...
10-foot	26	328	970	105
12-foot	7	510	685	351
16-foot	21	658	1080	155

FACTORS OF COST AND BASIS OF CHARGES

The important factors of cost in combine harvester operation are man labor, tractor work, horse work, use of truck, gasoline and lubricants, repairs, and interest and depreciation on the machine. Other minor costs are taxes, insurance, and storage. The latter items are not included in this study because complete data are not available. Many of the combines had been purchased during the year of the study and shelter had not yet been provided. Some of the machines that had been used the previous year had not been sheltered during the winter. Since they are of minor importance their omission will not affect materially conclusions based on the costs presented.

Man Labor

Man labor in this study has been divided into three classifications, operating windrower, operating combine, and hauling grain. The usual crew for windrowing is one man who drives the tractor or horses and operates the machine. In a few cases two men were used. The usual crew for combining is two men, a tractor driver and a machine operator. In some instances one man drove the tractor and operated the 10-foot combine. Eleven of the twenty-six 10-foot machines were handled in whole or in part by one man. Occasionally a second man was used in addition to the tractor driver, especially with the larger machines. Man labor has been charged at 40 cents per hour, the usual rate paid for harvest labor on the farms studied.

Tractor Work

All combines included in this study were tractor drawn. Forty of the 47 windrowers were drawn by tractors, 6 partly by tractors and partly by horses, and one by horses, exclusively. The tractors used ranged from a 2-plow to a 4-plow size. The 2-plow tractor had ample power to handle the smaller combines and the windrowers. A 3-plow tractor was necessary for the 16-foot combines and was generally used with the 12-foot size. Since all combines except the one 8-foot machine

were equipped with auxiliary motors, the tractors were used only for drawing the machines. The 8-foot machine was equipped with a power take-off attachment so that the tractor operated the threshing and cleaning mechanism as well as pulling the combine. A 3-plow tractor was used. Tractor work has been charged at the following rates: 80 cents per hour for drawing a 12-foot windrower, 90 cents for a 10-foot combine, and $1 per hour for all other tractor work. Tractor cost data were not obtained. These cost rates are computed from the results of a survey of tractor costs in 1929.[3]

Horse Work

Horses were used to draw windrowers and to haul grain. Only one combine owner used horses exclusively for windrowing and 6 used them for part of it. Ordinarily 4 horses are used to draw a windrower but in two cases only 3 were used. Eighteen farmers used horses exclusively to haul grain and 14 used horses for part of the work and trucks for the remainder. Horse labor is charged at 12 cents per hour. The rate was obtained from farm accounting studies in several sections of the state.

Use of Truck

Trucks were used exclusively for hauling grain on 23 farms and for part of the work on 14 others. The use of trucks is charged at 15 cents per mile. The rate is based on farm accounting studies covering farm trucks.

Gasoline and Lubricants

Gasoline, oil, and grease reported in this study includes only that used for the auxiliary motor and combine. It does not include the fuel and lubricants for the tractor since they are included in the tractor charge. All combines included in this study were equipped with auxiliary motors except the one 8-foot machine which was operated by power take-off from the tractor. A 20 horse-power motor was the common size on the 10-foot and 12-foot combines and a 35 horse-power motor on the 16-foot machines. There was, however, considerable variation in the size of auxiliary motor used even on machines of the same size. Gasoline is charged at 18 cents per gallon and lubricating oil at 70 cents per gallon.

Repairs

Most of the combines included in the study have been in use only one or two seasons. The cost of repairs has been low, as many broken parts have been replaced free by the dealer. For this reason a flat repair charge of 10 cents per acre has been used for all machines. The

[3] The Divisions of Farm Management and Agricultural Economics and of Agricultural Engineering of the Minnesota Agricultural Experiment Station made a survey study of costs of tractor operation on 291 Minnesota farms in 1929. These data are in process of preparation for publication.

rate is obtained from a study of a large number of combines made by the United States Department of Agriculture in the Great Plains.[4]

Interest and Depreciation

The average purchase price of the combines studied was as follows: 8-foot size, $785; 10-foot size, $1,438; 12-foot size, $1,754, and 16-foot size, $2,290. The price includes all extra equipment except windrowers and pick-up attachments. As noted in the previous paragraph, auxiliary motors are included in the equipment on all 10-foot, 12-foot, and 16-foot machines. All but two machines were equipped with straw spreaders. A straw buncher was used on one 16-foot machine and a 3-foot extension cut on one 12-foot machine. All but one machine was equipped with grain tanks. A 30-bushel tank was the usual size on the smaller machines and a 60-bushel tank on the 16-foot machine. The average purchase price of the 12-foot windrowers was $257 and of the 16-foot machines, $394. Twelve-foot windrowers were used with the 10-foot and 12-foot machines and 16-foot windrowers with the 16-foot machines. The average purchase price of the pick-up attachment for the 10-foot or 12-foot machine was $87 and for the 16-foot machine, $121.

The combine has been in use for so short a time in Minnesota that it is impossible to get exact information as to their length of life. The operators estimated their life at from 8 to 10 years. Most of the estimates were for 10 years. Two hundred fifty-seven combine operators in the Great Plains area estimated the life of their machines at an average of 8.3 years.[5] As the small combine has been on the market only a short time, improvements are being added each year. Even tho the present machines may last 10 years, they are likely to be replaced by newer types before that time. A conservative estimate of 8 years has been adopted as the life of the combines in this study. One eighth of the purchase price has been charged as the annual depreciation rate. The same rate has been used for windrowers and pick-up attachments. Interest has been charged at 6 per cent on the average investment[6] in the machine and equipment. Table IV gives a summary of the annual interest and depreciation charges per machine thus computed. On the basis of a 10-year working life the total annual charges for both items would be approximately 16 per cent less than shown in the table. While the authors feel that the 8-year life is a safer basis for cost comparison, the reader may adjust the item on this basis if it is felt that this figure is too low.

[4] Reynoldson, L. A., Kefers, R. S., Marten, J. H., Humphries, W. A., The Combined Harvester Thresher in the Great Plains. U. S. Dept. Agr., Technical Bull 70, February, 1928.

[5] U. S. Dept. Agr., Technical Bull. 70.

[6] The average investment was determined according to the rule: average investment $= \frac{\text{first cost} \times (\text{years of service} + 1)}{\text{years of service} \times 2}$

TABLE IV

AVERAGE ANNUAL INTEREST AND DEPRECIATION CHARGES PER MACHINE FOR DIFFERENT SIZES OF COMBINES AND WINDROWERS

Size	Average purchase price	Annual depreciation (8-year life)	Annual interest charge at 6 per cent	Annual interest and depreciation charge
8-foot combine	$ 785	$ 98.13	$26.49	$124.62
10-foot combine	1438	179.75	48.53	228.28
12-foot combine	1754	219.25	59.20	278.45
16-foot combine	2290	286.25	77.29	363.54
12-foot windrower and pick-up	344	43.00	11.61	54.61
16-foot windrower and pick-up	515	64.38	17.38	81.76

Summary of Factors of Cost and Performance

A summary of the physical factors of cost and performance for the different sizes of combines and data covering windrowers are presented in Table V. Separate figures for threshing grain picked up from the windrow as distinguished from combining standing grain are not given as no differences in time spent or materials used were found. The total acreage for each size of machine has been adjusted in proportion to the width of cut. The average acreage per cutting foot for all machines was determined and the figure multiplied by the cutting width of each size of combine. Since the number of records for the different sizes is small and a wide variation occurs between different farms even for the same size machine, this adjusted acreage will give a better picture of the relative capacity and of relative costs for the different sizes of combines than would the actual average acreage figure for each size.

TABLE V

FACTORS OF COST AND PERFORMANCE IN COMBINING AND WINDROWING

	Combining				Windrowing		
Width of cut	8-ft.	10-ft.	12-ft.	16-ft.	12-ft.*	12-ft.†	16-ft.
No. of farms	1	26	7	21	7	23	20
Total acres	298	372	446	595	377	377	502
Acres per hour	2.1	2.5	3.1	4.0	2.7	3.8	5.0
Man hours per acre	.48	.63	.69	.56	.37	.26	.20
Horse hours per acre	..	..	..	..	1.37	..	..
Tractor hours per acre	.48	.39	.32	.25	..	.26	.20
Fuel and oil, auxiliary engine							
Gasoline, gal. per acre	..	.50	.45	.60	..	..	..
Lubricating oil, qts. per acre	..	.07	.07	.05	..	..	..
Hauling grain							
Man hours per acre	.40	.40	.40	.33	..	..	..
Horse hours per acre	..	.40	.40	.20	..	..	..
Truck miles per acre	1.20	.80	.80	1.00	..	..	..

* Horse-drawn. † Tractor-drawn.

The man labor per acre is lowest for the smallest combine because one man operated both tractor and combine. Since some of the 10-foot machines were operated by one man the rate is lower than for the 12-foot machine. The 16-foot size, however, offsets this disadvantage be-

cause of its larger capacity per hour. The tractor-drawn windrowers had a distinct advantage over the horse-drawn because of the greater speed.

Daily Capacity of Combines and Windrowers

The hourly capacity of both combines and windrowers is given in Table V. The number of hours per day that a combine can be used successfully depends upon weather conditions and the kind of grain to be harvested, whether standing or windrowed. The usual time of starting the combine in the morning on windrowed grain was nine o'clock and for straight combining, ten o'clock. When there was little or no dew, windrow combining was sometimes started as early as seven o'clock, but combining of standing grain was never started before nine o'clock. If there was a heavy dew, high humidity, or rain the previous day, starting much later was necessary. The usual quitting time in the evening was seven o'clock altho straight combining was sometimes continued as late as ten o'clock and windrow combining until midnight. If an hour is allowed out at noon, the length of combine day based on usual starting and quitting time is 8 hours for straight combining and 9 hours for windrow combining. Windrowers were started as early as half-past six in the morning and ran as late as ten at night but the usual starting time was eight o'clock and the quitting time seven. This would indicate a working day of about 10 hours in the field if the same allowance is made for time out at noon. The length of working day for the windrower is not so significant as for the combine since windrowing can be done at times when conditions are not suitable for combining. A common practice with some operators is to use the windrower in the morning and the combine in the afternoon, as conditions are usually much more favorable for combining then.

TABLE VI

ACREAGE HARVESTED DAILY BY COMBINES OF DIFFERENT SIZES
(Based on representative length of work day)

Size of combine	Acres per hour	Straight combining		Combining from windrow	
		Hours per day	Acres per day	Hours per day	Acres per day
8-foot	2.1	8	16.8	9	18.9
10-foot	2.5	8	20.0	9	22.5
12-foot	3.1	8	24.8	9	27.9
16-foot	4.0	8	32.0	9	36.0

A summary of the data on the daily capacity of combines of different sizes is presented in Table VI. These are based on the representative length of work day. Weather conditions may greatly reduce this rate or they may make possible a considerable increase in length if the operators are willing to work long hours and reduce to a minimum the

time for meals. On the basis of a ten-hour day, a 12-foot horse-drawn windrower will cut 27 acres daily, a 12-foot tractor-drawn machine 38 acres, and a 16-foot tractor-drawn machine 50 acres.

COST OF COMBINING AND WINDROWING

Combine Harvesting

A comparison of the cost per acre of combine harvesting by the four sizes of machines studied is given in Table VII. The operating costs per acre are practically identical for the three smaller sizes. The more efficient use of labor and power by the 16-foot machine results in slightly lower operating costs. Because of the relatively low purchase price of the 8-foot size, interest and depreciation charges are materially less than for the others. The purchase price per cutting foot for the 8-foot machine was $98 and for the 10-foot, 12-foot, and 16-foot sizes, $144, $146, and $143, respectively. Since the acreage harvested has been adjusted in line with the relative size of the machines and since a uniform rate of interest and depreciation has been used, the interest and depreciation charge per acre varies directly with the purchase price per cutting foot. The costs in Table VII do not include any charge for windrowing grain or for hauling grain away from the combine. The windrower costs will be given later. As grain-hauling costs vary with the distance hauled, they have been omitted but will be given later when comparisons are made with binder-thresher costs.

TABLE VII

COST PER ACRE OF COMBINE THRESHING, 1928 AND 1929

	Size of combine			
	8-ft.	10-ft.	12-ft.	16-ft.
Number of farms	1	26	7	21
Acres harvested per farm	298	372	446	595
Acres harvested per hour	2.1	2.5	3.1	4.0
Man labor	$.19	$.25	$.28	$.22
Tractor work	.48	.35	.32	.25
Gasoline	..	.09	.09	.11
Oil	..	.01	.01	.01
Repairs	.10	.10	.10	.10
Operating costs	$.77	$.80	$.80	$.69
Interest and depreciation	.42	.61	.62	.61
Total	$1.19	$1.41	$1.42	$1.30

The costs for the 8-foot combine are based on reports from only one machine. However, the factors of operating cost check so closely with those for the larger machines for which records are available, when allowance is made for differences in width of cut, that this one report seems to be representative and in line with the costs for other sizes.

The time spent per acre as indicated by the tractor hours recorded in Table V is about double that of the 16-foot machine which cuts twice as wide a swath. In fact, the relation of tractor hours per acre for each size group is so nearly in proportion to the size that one may conclude that, as far as rate of performance and labor is concerned, the data for the individual size groups are reasonably accurate and representative. The man labor for the 8-foot machine, because it is the same as the tractor work, may for the same reason be accepted. It is a one-man machine. The repair charges are supplied on the same basis as for the other sizes. As far as operating costs are concerned, therefore, the use of a single report appears justified. Interest and depreciation is computed exactly as in other sized groups. The number of machines in a group is significant only in so far as it gives a fairer picture of what farmers are paying for combines. As 8-foot machines were not in general use in 1929 there is no basis for judging this fact. It appears from the prices quoted by the company manufacturing the particular 8-foot machine included in this study that the regular price in Minnesota will be about $100 higher in 1930 than was paid by the owner of this machine. In that case the annual interest and depreciation charge would be increased by $15.88 and the acre cost by a little more than five cents.

Another factor that should be considered in comparing the cost of combine operation of the 8-foot machine with the other sizes is that this machine was operated with a power take-off whereas all others were equipped with auxiliary engines. No data are available as to the relative efficiency of the two methods of supplying power to a combine. However, the close correspondence in rate of performance and labor requirements between the power take-off and the auxiliary engine indicates that, at least in this study, the method of applying power was not significant.

The costs presented are average. There was a wide variation in costs on the different farms. The most important factor causing this variation is acreage harvested annually per combine. The influence of this factor is brought out in Table VIII. The cost for each acreage group is obtained by adding to the operating cost per acre (Table VII) an amount obtained by dividing the total annual interest and depreciation charge by the number of acres in that group. Since the total interest and depreciation figure is a constant amount, the per acre charge diminishes as the number of acres over which it is charged increases. Obviously it is not entirely accurate to assume that the annual depreciation is the same regardless of the acreage harvested. On the other hand, the depreciation is not directly proportional to acres of work done. However, the error owing to the assumption of a constant depreciation is slight and does not invalidate the general comparisons presented. The

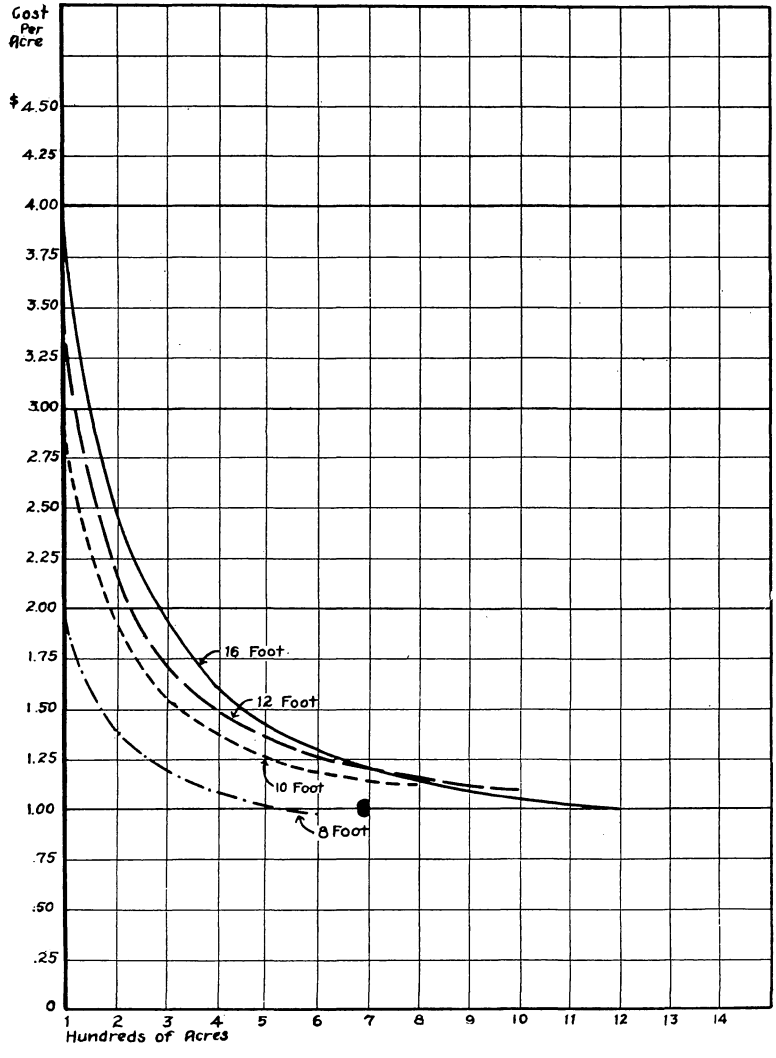

Fig. 3. Effect of Acreage Harvested Annually per Combine on Cost of Combine Harvesting

The larger the acreage harvested annually by a single combine the lower the cost is per acre. Operating costs vary directly with the acreage but interest and depreciation constitute a more or less fixed overhead charge that is influenced but little by the work done.

same relationship is shown graphically in Figure 3. These data are useful in selecting the size of machine best adapted to a particular acreage on a given farm. They also point out the importance of the full utilization of a machine to reduce costs. As indicated in the description of the farms and the discussion of work done by combines, operators secure a sufficient acreage to provide economic utilization of their machine by renting additional land and by doing custom work for others.

TABLE VIII

EFFECT OF ACREAGE HARVESTED ANNUALLY PER COMBINE ON COST PER ACRE

Acres harvested annually	Size of combine			
	8-foot	10-foot	12-foot	16-foot
100	$2.02	$3.08	$3.58	$4.33
200	1.39	1.94	2.19	2.51
300	1.19	1.56	1.73	1.90
400	1.08	1.37	1.50	1.60
500	1.02	1.26	1.36	1.42
600	.98	1.18	1.26	1.30
700	...	1.13	1.20	1.21
800	...	1.09	1.15	1.14
900	...	...	1.11	1.09
1000	...	...	1.08	1.05
1100	...	...	...	1.02
1200	...	...	...	0.99

The maximum acreage for which costs are computed for any particular size of combine represents approximately the maximum acreage that could be harvested in a season by one machine under ordinary conditions. This maximum performance would only be possible with a succession of crops ripening at different periods. To cut 1,200 acres in one season with a 16-foot combine, working the usual length of day, it would require 34 days of work if combining from the windrow and 38 days for straight combining. Since there would always be some delay owing to weather conditions, the harvest season would extend over a period of at least six weeks even if the machine were operated seven days a week. If conditions were such as to permit longer working days this could be reduced somewhat. One operator with a 10-foot combine harvested 970 acres in 1929. He worked an average of ten hours per day, lost no time because of weather, and lost only one day while waiting for repairs. Such a record is only possible under exceptionally favorable harvest conditions.

In comparing the costs for machines of different sizes it is evident that the costs for the 8-foot machine are lower, up to the limit of its capacity, than any of the other sizes. Even if the figures are adjusted for a higher purchase price, as suggested in the discussion of the costs presented in Table VII, the small machine still has an advantage. However, it should be remembered that the small capacity of this machine

is a limiting factor in its adaptation. It might appear wise economy to use two 8-foot combines instead of one 16-foot machine. This would necessitate the purchase of another tractor. If the farm were already equipped with sufficient tractor power, the harvesting operations would have to bear all the costs of the second tractor and would result in a much higher tractor rate than that used in the present study. In case a second tractor were already available on the farm the use of the two 8-foot combines might prove economical. There is another disadvantage of the small combine machine. Most grain harvested with a combine in this state is first windrowed. The capacity of an 8-foot windrower would be so small as to make this operation expensive from the labor standpoint. It is only for straight combining that the advantage of the 8-foot machine obtains. As will be pointed out later, 78 per cent of the acreage threshed by the combines included in this study was first windrowed and the use of the windrower is increasing. In view of this fact it appears that the 8-foot machine, even tho economical under certain conditions, has a limited adaptation.

Windrowing

The cost of windrowing is in addition to that of combining. Table IX gives cost per acre of operating 12-foot and 16-foot windrowers. There is a little difference in acre costs between horse-drawn and tractor-drawn windrowers.

TABLE IX

COST PER ACRE OF WINDROWING GRAIN

	Size of windrower		
	12-foot		16-foot
	Horse-drawn	Tractor-drawn	Tractor-drawn
Number farms	7	23	20
Acres per farm	377	377	502
Acres per hour	2.7	3.8	5.0
Man labor	$0.15	$0.10	$0.08
Horse work	.16	..	..
Tractor work	..	.21	.20
Operating costs	$0.31	$0.31	$0.28
Interest and depreciation	.15	.15	.16
Total costs	$0.46	$0.46	$0.44

The tractor-drawn machines have the advantage of larger capacity. The acre costs for the 16-foot windrower is only slightly below that of the smaller size. The cost of 44 cents to 46 cents per acre represents the extra cost the combine operator must pay for the windrowing operation in addition to the cost of picking up and threshing with a combine. The cost of windrowing decreases with increases in the acreage cut annually the same as was noted in case of the combine. The decrease,

however, is not so marked since interest and depreciation contribute a smaller proportion of the total cost. This effect of acreage cut on costs is shown in Table X.

TABLE X

EFFECT OF ACREAGE HARVESTED ANNUALLY PER WINDROWER ON COST PER ACRE

Acreage cut annually per windrower	Size of windrower	
	12-foot	16-foot
100	$.86	$1.10
200	.58	.69
300	.49	.55
400	.45	.48
500	.42	.44
600	.40	.42
700	.39	.40
800	.38	.38
900	.37	.37
1000	.37	.36
1100	..	.35
1200	..	.35

The interest and depreciation charge includes interest and depreciation on the pick-up attachment as well as on the windrower since the use of this attachment is directly associated with the windrowing operation.

Comparison of Combine Costs with Binder-Thresher Costs

Since the combine replaces the binder and stationary thresher a knowledge of the cost of binder-thresher harvest is necessary to determine what economies, if any, may be effected by combine harvesting. Some data on binder-thresher costs are presented in Table XI. The costs are computed from detailed cost records on groups of farms in three sections of the state. Figures for northwestern Minnesota are from records in Polk County, for southwestern Minnesota from records in Rock and Nobles Counties, and for southeastern Minnesota from records in Steele County. Man labor and horse work are charged at the same rates as used in the combine study. The binder charge includes interest, depreciation, and repairs. Twine is charged at current prices and threshing at the usual custom rate per bushel prevailing in the community. The acreage harvested represents as nearly as could be determined, the annual capacity of binders on the 25 per cent of the farms studied that were using their binders nearest to capacity. It probably represents, for the type of farming involved, a use more nearly to full capacity than do the combine figures. Since the fixed overhead items of interest and depreciation constitute a relatively minor part of the total cost in binder harvest, the matter of acreage covered is not so important a factor in economy as it is with combines.

TABLE XI

COST PER ACRE OF BINDER-STATIONARY THRESHER HARVEST

	8-foot binder		7-foot binder
	N.W. Minn.	S.W. Minn.	S.E. Minn.
Acres harvested	200	145	101
Man labor	$1.40	$2.04	$2.40
Horse work	.60	1.07	1.02
Binder charge	.22	.25	.25
Twine	.28	.34	.36
Threshing	.95	1.13	1.50
	$3.45	$4.83	$5.53

The cost of binder-thresher harvest is materially higher in southeastern Minnesota than in the northwestern part. Southeastern Minnesota farms from which the binder costs were obtained are dairy farms. They are smaller in total size and in individual fields. Smaller threshing outfits are used and, because of the time spent on livestock chores morning and evening, the working day is shorter. Most of the grain is hauled to the farmstead instead of being threshed in the field as is commonly done in northwestern Minnesota. The yields of both grain and straw are higher. The costs of binder-thresher harvest in southwestern Minnesota are intermediate between the other two districts. The size of the farms is also intermediate. They are beef cattle and hog farms and hence there are less chores to interfere with field work than on dairy farms. The sizes of binders indicated are the usual sizes used in the respective areas from which the records were obtained.

In Table XII the binder-thresher harvesting costs as presented in Table XI and the combine and windrower costs, Table VII and IX, are compared. To make the combine costs comparable with the binder-thresher costs a charge for grain hauling has been added to the items presented in the previous tables. The charge is based on the factors cost given in Table V, charged at the rates mentioned in the discussion of combine costs. Costs for both harvesting of standing grain and for the combined operations of windrowing and threshing from the windrow with the aid of a pick-up attachment are also presented. The item of man labor is entered separate from the other items of cost since it is in this factor that the difference is most striking and most significant. With each size of combine, even with the extra operation of windrowing included, the combine costs are materially less than those of binder-thresher harvest. In case of the comparison most favorable to the binder-thresher, that of the 8-foot binder in northwestern Minnesota with the 10-foot or 12-foot combine and windrower, shows a combine cost less than two-thirds as large as with the other method. The labor cost is only about one-third as much. Five hundred ninety-five acres of grain can be windrowed and combined with

TABLE XII

COMPARATIVE COST PER ACRE OF BINDER-THRESHER AND COMBINE HARVESTING

Method of harvest	Size of machine	Acres harvested annually	Costs per acre		
			Man labor	Other	Total
Binder, S.E. Minnesota....	7-foot	101	$2.40	$3.13	$5.53
Binder, S.W. Minnesota....	8-foot	145	2.04	2.79	4.83
Binder, N.W. Minnesota....	8-foot	200	1.40	2.05	3.45
Combine	8-foot	298	.35	1.18	1.53
Combine	10-foot	372	.41	1.33	1.74
Combine	12-foot	446	.44	1.31	1.75
Combine	16-foot	595	.35	1.25	1.60
Combine and windrower....	10-foot	372	.51	1.69	2.20
Combine and windrower....	12-foot	446	.54	1.67	2.21
Combine and windrower....	16-foot	595	.43	1.61	2.04

a 16-foot machine with less total labor than is required for 200 acres with an 8-foot binder and a stationary thresher.

Altho the horse-drawn binder is the usual method of harvesting grain in Minnesota at the present time the tractor-binder has come into the picture within the past few years. A comparison of combine harvesting costs with those of other methods would not be complete without some mention of this machine. Only one tractor-binder was in use on the farms included in this study. One farmer used a 10-foot tractor-binder in 1927 and in 1928 turned it in on the purchase of a 10-foot combine and a 12-foot windrower. A comparison of costs for the two methods of harvesting and threshing is given in Table XIII. A saving of 25 per cent in total costs and of 43 per cent in man labor was effected by the use of the combine. While this is only one instance the difference is sufficient to indicate a substantial saving for the combine.

TABLE XIII

A COMPARISON OF THE COST OF HARVESTING AND THRESHING BY DIFFERENT METHODS ON THE SAME FARM

	1927	1928, 1929
	10-ft. tractor-binder and stationary thresher	10-ft. combine and 12-foot windrower
Acres covered	303	326
Man labor	$1.30	$ .74
Horse work	.39	.18
Tractor work	.35	.58
Machine charge	.21	1.13
Twine cost	.27	...
Threshing charge	1.00	...
Total cost	$3.52	$2.63

In comparing combine harvesting costs with those of binder-thresher harvest, some allowance must be made for the fact that the two operations are not entirely comparable. In using the stationary thresher the straw is stacked or at least blown into a pile. Often the stack is

close to the barns or yards where it is easily available for feed or bedding. It may even be blown directly into the barn. The combine, on the other hand, leaves the straw scattered over the field. The significance of this difference will be discussed at greater length later.

FARMERS' EXPERIENCE WITH COMBINE HARVESTERS

In determining the economic adaptation of the combine it is as important to know the quality of work done and the special problems involved as it is the relative cost as compared with other methods of harvesting. Each operator included in this study was asked his experience regarding the condition of the combine-harvested grain, the advantages and disadvantages of the combine over the binder and stationary thresher, his use of the windrower, and the degree of satisfaction with which his combine equipment was handling his harvesting operations. Eighteen operators answered the questions in 1928 and 42 operators in 1929, or a little more than one third of all combine owners in the state. The harvest season in 1928 was unusually wet and generally unfavorable for harvesting by any method. The 1929 harvest season was unusually dry and very favorable for harvest work. There was, however, little difference in the problems reported or in the degree of satisfaction expressed between the two years. In evaluating the answers some allowance must be made for the fact that the men had already committed themselves to the purchase of a combine. Naturally they would be more inclined to defend their judgment than to admit they had made an unwise investment. Still many of the factors were possible of direct objective measurement. All of the operators co-operating in this study were interested in getting a fair appraisal of the profitableness of a combine and it is not likely that there was sufficient bias in their answers to alter materially any conclusions based on the replies.

CONDITION, QUALITY, AND LOSSES OF COMBINE GRAIN

Unless the windrower is used there must be a considerable delay between binder-harvest time and the time when grain is dry enough to handle successfully with a combine. There is always a possibility that the standing grain may be damaged by hail, wind, or rain during this period. Ninety per cent of the operators reported no damage and 10 per cent slight damage for certain individual crops. One-third reporting damage said the same damage would probably have resulted over most of the field even if the binder had started at the usual time.

Twenty per cent of the operators reported grain heating in the bin. The quantity damaged was seldom more than one or two loads

on a farm. Barley was damaged most frequently as it is the first grain to ripen and in the hurry to start harvesting, some farmers cut it too soon. Sometimes the damage was owing to an early start in the morning before the dew was off. Generally the damage was slight. One farmer reported that his barley was reduced 10 per cent in feeding value by heating in the bin and another reported that 300 bushels was only fit for hog feed.

Only two farmers reported any combine grain docked at the elevator for moisture. In one case rye was docked 5 per cent and in the other wheat was reduced one grade. Twelve per cent of those reporting had combined grain refused at the elevator. The reasons for rejection were: wheat, bleached; flax, green weed seeds and sweet clover stems; and barley, musty. In two cases grain was refused because the elevator was full and it was not possible to move the combine grain from one bin to another to dry to prevent heating. None of the elevators had special equipment for conditioning combine grain nor did most of the farmers. One operator had ventilated bins in the granary and several others had elevators in the granaries enabling them to move the grain from bin to bin. Two farmers avoided trouble with early threshed grain by starting the harvest with a binder and delaying the use of the combine until the grain was sufficiently dry. Two others used the binder to harvest grain containing so many green weeds that if threshed with a combine the grain might not keep. In general, however, a condition of grain satisfactory for storage was secured by cutting the grain with a windrower and allowing it to dry in the windrow. Merely delaying harvest may be sufficient to secure proper conditions in combine-threshed grain unless the grain ripens unevenly or green weeds are present. The latter condition necessitates the use of the windrower to assure a condition satisfactory for storage.

ADVANTAGES AND DISADVANTAGES OF COMBINE HARVESTING

The principal advantages and disadvantages of combine harvesting over the binder-thresher method as reported by the combine operators are given on page 24. The percentage of operators reporting each item is also given. The percentage figure does not mean that only this share of the combine operators incurred these advantages or disadvantages; it merely indicates that this proportion of the total number interviewed, mentioned these points. For example, all combine operators eliminated the use of twine but only about one third of them mentioned it in their reports. The percentage figures indicate the relative degree with which the points impressed the combine operators rather than the frequency with which they were experienced. There is some duplication in several of the items.

Advantages	Per Cent
Saves labor	89
Lowers cost of harvesting	35
Saves twine	31
Eliminates feeding a threshing crew	25
Makes possible earlier plowing	24
Shortens harvest season	24
Saves grain	16
Makes harvest work easier	13
Puts straw on land	10
Eliminates a hired crew	9
Eliminates exchange labor	4

Disadvantages	Per Cent
None	42
Loses straw	17
Too heavy for wet ground	17
Working day too short	8
Grain deteriorates in awaiting combine	4
Combine grain contains excessive moisture	4
Green weeds prevent satisfactory work	2
Uneven ripening prevents satisfactory work	2
Initial investment too high	2

It is interesting to note, however, that every operator reported at least one distinct advantage for the combine whereas slightly more than half reported any disadvantages. Some of these points merit further consideration.

A Labor Saver

The most significant advantage of the combine is saving of man labor. Not only does this reduce the total cost of harvest but it eliminates, in most cases, hiring extra harvest labor or the inconvenience of exchange labor. Extra labor is likely to be both scarce and high priced at harvest time. A crew of three men can usually handle a combine; and at most four men are needed with the largest sizes. On farms as large as those on which the combines are now used the

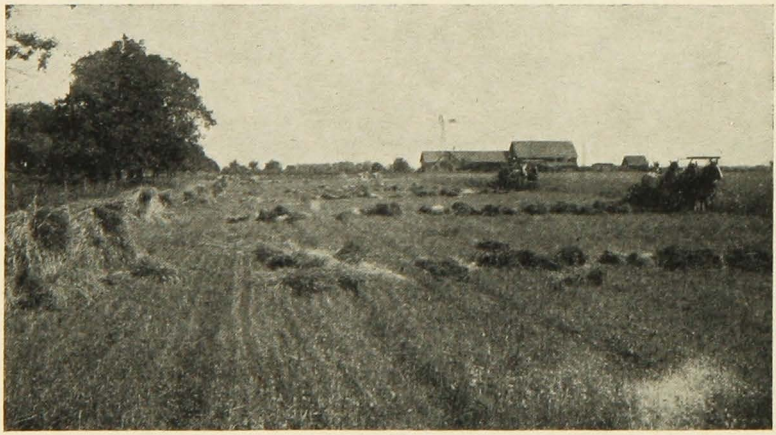

Fig. 4. Binder Harvest on a Minnesota Farm

Binder harvest and shocking require more labor than the entire operation of cutting and threshing with a combine. Binder harvest, however, has the advantage of saving and curing the straw and of reducing the moisture content of grain so that it may be stored safely.

regular labor supply will handle all harvest work without resorting to exchanging help with neighbors or hiring the high-priced and often unsatisfactory transient labor available at harvest time. This also relieves the housewife of the burden of feeding the larger crew needed with the binder-thresher method.

Reduces Total Harvesting Cost

The lower cost of combine harvesting as compared to binder threshing has already been considered in the discussion of costs. The saving in labor and twine impresses the operators most strongly. On the other hand, the initial investment in the combine and equipment is so much more than in a binder or even two or three binders that it looms large in the farmer's consideration. A 10-foot combine, the smallest size in common use in the state, costs approximately six times as much as an 8-foot binder. Where a farmer is able to utilize a combine to full capacity, however, this first cost is not so significant. A 10-foot combine can harvest several times as large an acreage of grain in a season as can an 8-foot binder. If, in addition, the investment in the thresher is also considered the extra investment in the combine loses its significance.

Shortens the Harvest Season

The combine makes possible a speeding up of the whole harvesting process. It is true that unless the windrower is used, harvest cannot be started as early as with a binder. On the other hand, there is much more delay between binder-harvest and threshing than between windrowing and combining. The combine completes the work of clearing the field in one operation and makes early plowing possible. As soon as a field is combined it can be plowed; it is not necessary to wait for the threshing crew to clear the field of shocks. On grain farms where weeds are usually a serious menace to crops, early fall plowing is an important factor in their control. The speeding up of the harvesting work leaves more time for this task.

Loss of Straw

Probably one of the most serious problems of combine adaptation on the livestock farm is the matter of straw recovery. On the grain farm where no use is made of the straw, spreading it back on the land by the combine is a decided advantage as its fertilizer and humus value is thus utilized. But to the livestock farmer it represents a loss. Various methods of straw recovery were attempted. Nearly a fourth of all combine owners in this study used a binder to harvest part of their crop so as to save the straw. Several others dropped the straw in a windrow behind the combine instead of spreading it and later tried various methods of recovering it. The common method

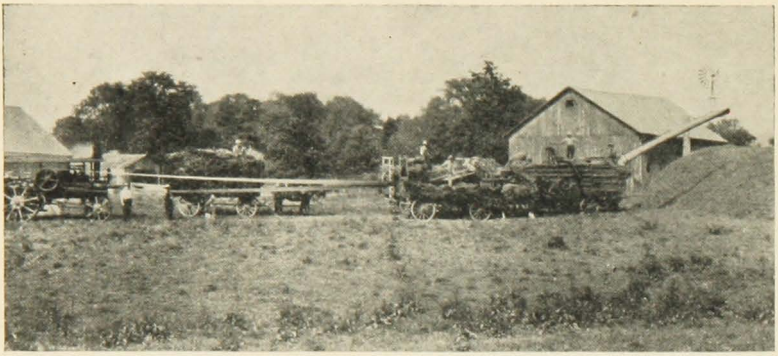

Fig. 5. A Typical Threshing Scene in Minnesota

The stationary thresher requires a large crew of men. The cost of threshing alone often exceeds the entire cost of cutting and threshing with the combine. An important advantage of the stationary thresher over the combine on the livestock farm is that the straw is saved and may be stacked in the barnyard where it is to be used.

was to throw several windrows together with a side delivery rake, load with a hay loader, and haul to the barn or stack. In a few cases a buck rake was used and the straw was stacked in the field. The average amount of straw recovered was 0.4 ton per acre and the cost was approximately $2 per ton. Another device for straw recovery that is being tried is a baling attachment at the rear of the combine which bales the straw instead of leaving it spread on the ground. No figures on the extra cost of the baling operation are available. One difficulty that may be encountered with this method is the moisture content in the straw, especially if it contains green weeds. Straw commonly contains a higher percentage of moisture than the threshed grain. It may be possible to overcome this difficulty by the use of the windrower altho even in the windrow the heads lie on top and hence dry out more rapidly than does the straw. Even tho a satisfactory and economical method of straw recovery can be developed, less straw or at least straw of lower quality is obtained. Usually the combine or windrower is set to cut the grain somewhat higher than is commonly done with a binder. Many of the combines lack the capacity to handle all the straw and if an attempt is made to do so, it is necessary to travel at a lower rate of speed so that the threshing and cleaning mechanism can operate effectively. If the combining of standing grain is done it is necessary to let the grain stand until it is dead ripe. With the windrower the straw must be left out in the windrow to dry. Again after threshing, the straw is left in the windrow. Altho it can still be used for bedding, it has little feeding value as compared with straw cut with a binder while still somewhat green and cured in shocks.

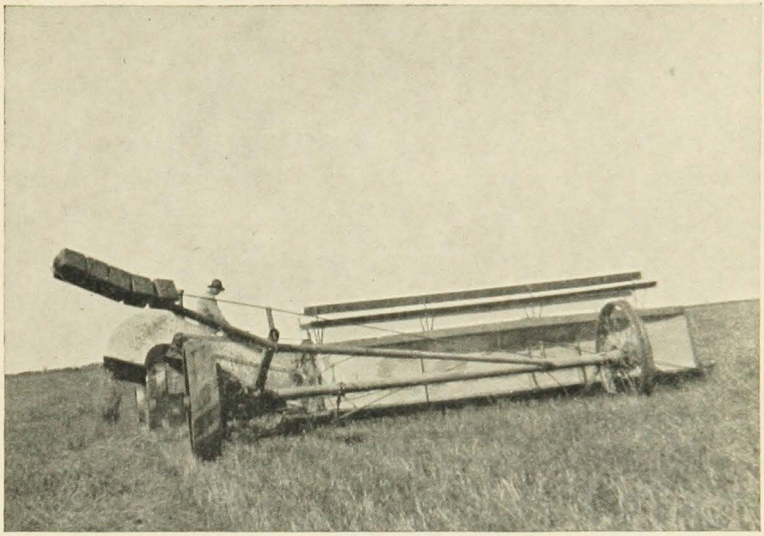

Fig. 6. The Windrower in Operation

The windrower consists of a center bar, reel, and platform. A 12- or 16-foot swath is cut and deposited by canvas carriers in a windrow about 3 feet wide. The windrower may discharge at the side as shown in the illustration or it may have two canvas carriers and discharge in the center.

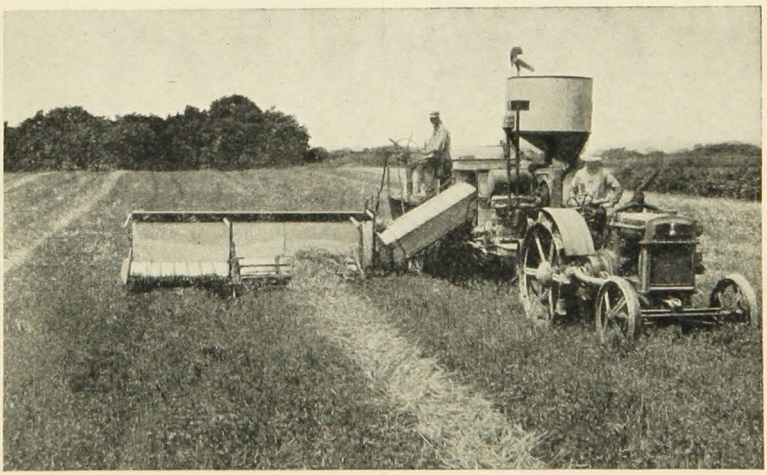

Fig. 7. Combining from the Windrow with a Pick-up Attachment

Grain is first cut and placed in the windrow as illustrated in Figure 6. When dry enough to store safely the grain is threshed with the combine by using an attachment to the cutter bar. The use of the windrower avoids losses from shattering of standing grain and reduces the moisture content of grain, which, because of green weeds, uneven ripening, or early harvest, would otherwise be too damp for safe storage.

USE OF THE WINDROWER

Another serious problem in adapting the combine to use in the humid sections is that of reducing the moisture content of the threshed grain to an amount so that it will keep in storage. This problem is complicated by the uneven ripening of grain and the presence of green weeds in the standing grain. The principal solution thus far devised is the use of the windrower. It also enables harvesting operations to be started before the grain is ready for combining, thus eliminating the weather risk on standing grain. The early start increases the capacity of a combine to some extent. Since windrowing can be done at a time when moisture conditions are not suitable for combining it does not compete seriously with the combine for the farmer's time. Eighty-five per cent of the combine operators included in this study used windrowers. Seventy-eight per cent of the acreage threshed with the combine was first windrowed. When asked as to their future plans for the windrowers, 61 per cent of the operators using them said they would use them for all their work, and 19 per cent for most of it. Most of those who did not have windrowers expressed the intention to purchase them. A few operators said they would use them only for weedy grain, in wet seasons, or for the early part of the harvest season. It seems wise economy to restrict the use of the windrower as much as can be safely done since it increases harvesting costs from 40 to 50 cents per acre. Most of these combine operators have had long experiences with binder harvest. They are not accustomed to delaying harvesting until the grain is in condition for the combine. With more experience they will be able to determine more accurately to what extent the windrower must be used and how long harvest may be delayed without serious loss. One of the serious losses that occur if grain is left standing until fit for straight combining is that of shattering. Different kinds of grain as well as different varieties of the same kind vary in their resistance to shattering. This is one of the agronomic problems mentioned in the introduction to this publication that is now being studied. Even a relatively small loss will more than offset the cost of windrowing. Until more information on the subject is available the windrower offers a form of insurance against such shattering losses.

ADEQUACY OF PRESENT COMBINE EQUIPMENT ON FARMS STUDIED

Each combine operator interviewed was asked whether the combine-harvester was more satisfactory for his conditions than the binder and stationary thresher. He also was asked what changes, if any, he intended to make in his equipment or would make if he had it to do

over again. Of 59 men interviewed, 55 expressed themselves as thoroly satisfied that the combine was more economical for their conditions and 3 were satisfied that the combine was better than the binder-thresher but needed certain improvements to be of greatest advantage. Only one operator was dissatisfied and wanted to sell his combine. He did indicate, however, that he believed his machine was defective and had not been properly serviced by the dealer and that if he had bought some other make he probably would have secured satisfactory operation. Twenty-five of the operators said they would make no changes in machine or equipment if they were to repeat their purchase. Seven men who did not have windrowers said they would purchase them and 7 intended to purchase larger machines. Others suggested the desirability of larger auxiliary motors. Only one operator would have preferred a smaller sized machine. The other changes suggested dealt largely with minor equipment and mechanical adjustments. From the answers it is apparent that the combine is giving satisfactory service on most of the farms on which it has been introduced in Minnesota.

Place of the Combine in Minnesota Agriculture

The combines in Minnesota are confined, to a very considerable extent, to large farms specializing in small-grain production. It appears from this study that their use on such farms has been satisfactory and that they have effected a material reduction in harvesting costs. As there are many farms of this type in west central and northwestern Minnesota it seems probable that the use of combines will continue to increase. Throughout eastern and southern Minnesota, however, farms are smaller and more livestock is maintained. There is a marked shift from crop sale to livestock farming going on even in the west central and northwestern part of the state. The average size of farms in the state has been decreasing since 1910. It is therefore well to consider the factors that limit the substitution of the combine for binder-thresher harvest in order to determine its possible adaptation to the small farm or to the livestock farm. Three of the most important factors to be considered are: (1) a sufficient acreage per machine annually to keep down acre costs; (2) the handling of harvest operations to avoid losses and to assure the condition of threshed grain so that it can be stored safely; (3) some method of straw recovery at reasonable cost.

The first factor can be provided for in the case of the small farm by either custom work or co-operative ownership as is now the practice with stationary threshers. Even tho a sufficient acreage can be obtained in this way the combine is still at a disadvantage on the small farm. No data are available as to the relative economy of combines and binders on small fields but it seems reasonable to assume that the

amount of time spent in turning a large machine as frequently as is necessary on a small field may materially reduce its capacity. More frequent moves between fields and farms will further reduce the capacity. Small farms are usually more fully fenced and farm gates are seldom wide enough to accommodate a combine or windrower. These factors will tend to reduce the use of the combine on small farms even tho sufficient acreage to provide a full season's work may be available through co-operative ownership or custom work.

The second factor can be provided by the use of the windrower. Thus far it is the principal method to condition grain and avoid losses from allowing grain to stand till it is thoroly ripe and dry enough to store. This involves an extra expense but the cost of the two operations of windrowing and combining is still much lower than that of binder-thresher harvest.

The third factor mainly concerns the livestock farm. On the grain farm, leaving the straw on the field is an advantage rather than a disadvantage. On the livestock farm part of this loss may be avoided by using a binder to harvest a portion of the crop. Possibly sufficient straw may be secured from near-by farms where the supply exceeds the needs. However, straw is so fully utilized in many sections of southern Minnesota that the loss of it would prove a serious handicap to the livestock farmer. Only in so far as the saving in the cost of combine harvesting over the binder-thresher method is greater than the value of the straw lost or the cost of recovering it does the combine have a distinct advantage. In conclusion it may be said that the practice of doing custom work may make possible a wide extension of the use of the combine on small farms. The windrower has helped to solve the problem of condition and losses of grain. One of the important problems yet to be worked out before the combine is fully adapted to the livestcok farm is some satisfactory and economical method of straw recovery.

SUMMARY

The number of combines in use in Minnesota increased from 11 in 1927 to 110 in 1929.

Farms on which combines are used are more than three times as large as the average of the farms in the counties in which they are located; have 15 per cent more of the area in crops, and 11 per cent more of this crop area in small grain.

Crops harvested amounted to 479 acres per combine on the farms studied in 1928 and 1929. Twenty-three per cent of this was custom work.

Seventy-eight per cent of the acreage harvested was windrowed before combining.

The average rate of harvesting with an 8-foot combine is 2.1 acres per hour; with a 10-foot, 2.5 acres; with a 12-foot, 3.1 acres; and with a 16-foot combine, 4.0 acres per hour.

The usual length of work day in combining standing grain is 8 hours, and in combining windrowed grain, 9 hours.

The average rate of cutting grain with a 12-foot horse-drawn windrower is 2.7 acres per hour; with a 12-foot tractor-drawn machine, 3.8 acres per hour; and with a 16-foot tractor-drawn windrower, 5.0 acres per hour.

The average purchase price of an 8-foot combine was $785; of a 10-foot combine, $1,438; of a 12-foot, $1,754; and of a 16-foot, $2,290.

The average purchase price of a 12-foot windrower was $257; and of a 16-foot, $394. The average price of a pick-up attachment for a 10-foot of 12-food combine was $87; and for a 16-foot combine, $121.

The average cost per acre of cutting and threshing grain with an 8-foot combine was $1.53; with a 10-foot, $1.74 per acre; with a 12-foot size, $1.75; and with a 16-foot size, $1.60.

The average cost of windrowing grain with a 12-foot windrower was 46 cents per acre and with a 16-foot combine, 44 cents per acre.

The average cost of cutting grain with a binder and threshing with a stationary thresher was $3.45 per acre in northwestern Minnesota with an 8-foot binder; $4.83 per acre in southwestern Minnesota with an 8-foot binder; and $5.53 in southeastern Minnesota with a 7-foot binder.

The principal advantages of the combine over the binder-thresher method of harvest are saving of man labor; reduction of total costs; speeding up the harvesting operations; and on grain farms, the spreading of the straw on the land.

The principal disadvantages of the combine are the difficulty of reducing the moisture content of the threshed grain sufficiently that it may be stored safely and the loss of the straw.

Most of the difficulties in reducing the moisture content of the threshed grain can be overcome by the use of the windrower.

The lowering of the quality of the straw and the cost of its recovery are the principal difficulties in adapting the combine to livestock farms.